

A telephone conference was held on March 26, 2003 from approximately 9:00 to 10:00 CST to describe the insights Etymotic Research had obtained in the process of designing an array microphone that is coupled to hearing aids through their telecoil inputs. Participants were:

Mead C. Killion, Ph.D. (caller), electroacoustic and hearing aid engineer and president of Etymotic Research (ER), who had been active along with Stephen Berger and others in obtaining the measurements that formed the basis of the C63.19 ANSI standard on digital cellphone interference with hearing aids.

Harry Teder, retired former chief engineer of Telex Hearing Aid Division and hearing aid consultant with extensive telecoil engineering experience and himself a long-time telecoil user and who collaborated with Killion in a previously published paper on an inexpensive "suitcase lab" method for measuring the interference of cellphone RF "buzz" with hearing aid operation (Killion, Teder and Thoma, 2001, attached). Teder joined the conference call at Killion's request and was present until approximately 9:35.

FCC staff: Patrick Forster, engineer; Mindy Litell attorney; Greg Guice, attorney; Joseph Levin, economist.

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REVIEW

The call started with a brief review of the two well-know sources of buzz with digital telephones, especially TDMA and GSM (PCS) transmissions, which are a) the RF pulses (217 per second with GSM, each pulse lasting one-eighth of the period) and b) the magnetic pulses from the (especially battery-to-RF-power-output wiring) resulting from the current surges 217 times a second as the RF output is powered on and off. RF pulses, finding a place of rectification in the hearing aid circuitry, become a 217 Hz audio buzz signal that can interfere with telephone reception for a hearing aid wearer using either microphone or telecoil inputs. Magnetic pulses provide an additional source of buzz that can interfere with the telecoil reception even if the hearing aid has been made immune to RF.

It was the caller's belief that the RF problem had been essentially solved in the latest hearing aid designs, whose immunity made them impervious to the RF output directed towards the head of most present cellphones. For those using older-design hearing aids, the percentage who can use GSM or TDMA cellphones is improving as the RF output from cellphones directed toward the head continues to decrease by cellphone design.

The telecoil problem has been more difficult to solve, because both the RF and magnetic interference can cause a buzz in the hearing aid. Although the RF pickup has now been largely solved in present hearing aid designs, the magnetic

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buzz that is typically produced by the cellphone over nearly all the cellphone case (and in particular in the vicinity of the earphone) can not be distinguished by the hearing telecoil circuit from a similar buzz coming over the phone line. In other words, it cannot be blocked without blocking the desired speech signal as well. As in the case of the RF buzz, the magnetic buzz can often be strong enough to make reception unintelligible.

Harry Levitt of City University of New York Graduate School and Judy Harkins of Gaudellet College studied the signal-to-buzz ratio required for hearing aid wearers and found that for GSM buzz a 25 dB SBR (signal-to-buzz ratio) was required in order for 90% of their subjects to rate the reception acceptable. In a similar study, Teder and Killion found a 20 dB SBR was required for TDMA and a 25 dB SBR was required for GSM. (See Fig 1 showing both sets of data in Preves, 2003, attached, and).

RECENT WORK

Some time back at Etymotic Research's request, Teder attempted to employ a cancellation scheme to reduce the magnetic buzz field from the telephone. We and Teder reasoned (as have others) that if a sample of the current pulses to the RF output could be fed to a shaped coil positioned such as to cancel the offending buzz (i.e., to produce an out-of-phase but similar in magnitude canceling magnetic buzz) in the vicinity of the earphone. After some effort, Teder concluded that it did not seem practical. (Teder: Because the interfering magnetic field was distributed everywhere!)

We at ER became interested in the use of telecoil pickup in hearing aids for a new "Soede array microphone" that we were introducing (ER product number ER-72). This highly directional array microphone combines three individual directional microphones in an small array to provide a 7 to 10 dB improvement in acoustic signal-to-noise ratio in restaurants and the like for conventional hearing aid wearers. Since it was an accessory to a hearing aid, it required coupling with the hearing aid somehow. Ruling out direct wiring, we made measurements on possible telecoil coupling, assuming than a magnetic field similar to that required for landline telephones (30 to 80 mA/m magnetic field) would suffice.

One of our engineers made measurements of the magnetic buzz created by fluorescent lights and computer monitors, among other things, and found noise levels of 5 to 30 mA/m. In our lunchroom, for example, where most of us need to pick up a phone call now and then, anyone using a hearing aid in telecoil mode must hold their head at a funny angle to minimize the buzz enough to carry on a conversation because of our fluorescent lights. (Teder: But don't overstate the problem. On this telephone call I am using a telecoil pickup now at home, where there are no fluorescent lights, and it works fine.)

To illustrate the problem in terms of common experience, note that a problem occurs for all of us even without hearing aids: In normal circumstances where background noise is not a problem, normal conversational speech is received at the ear or hearing aid input at about 65 dB SPL. At a cocktail party, which in the caller's experience typically average 82 dBA SPL after the party has been in progress for a while, the talker may raise his or her voice to 85 dB SPL in order to be understood by those with normal hearing. (The reason for the difference between the 3 dB signal-to-noise ratio we tolerate at parties and the 25 dB SBR for 90% of the subjects in the buzz experiments mentioned above is probably because a) the buzz is an effective masker b) many of the experimental subjects had a significant loss of ability to hear in noise and c) the experimental question was not "just barely able to carry on a conversation" at a party but "acceptable for normal use" as I recall.)

At some "popular" restaurants the background noise can reach 90 dB, in which case the talker must raise his or her voice to 93 dB to be understood. (In those cases, the hearing aid wearer may well choose to reduce the gain, even if the internal automatic gain control circuit is well designed.)

By analogy with raising one's voice, it is possible to raise the telecoil signal to the equivalent of 85-95 dB SPL. To produce a 25 dB signal-to-buzz ratio with up to 30 mA/m buzz level requires a little over 500 mA/m signal strength. In the design of our "Link-it" telecoil driver for our array microphone, we allowed another 10 dB margin to work better with hearing aids whose telecoil is mounted at such an angle that ideal magnetic coupling may be hard to achieve, bringing the design goal up to approximately 1700 mA/m. (In practice, we obtain 2000-5000 mA/m field strength. The field strength can be easily reduced with a screw-driver trimmer when that high a field is not desirable for a given hearing aid/telecoil combination.) These levels are unusually high but entirely practical: We use a Class D driver and the total battery drain is less than 0.2 mA on a 1.4 Volt cell.

Note: Telecoils are sometimes mounted up and down to maximize performance with "loop" systems found in theatres and sometimes mounted along a line through the ears to maximize pickup with telephones, depending on the patient's needs. The extra drive level makes it possible to use a single magnetic field configuration for a variety of telecoil locations.

When we measured the magnetic buzz level of several digital cellphones, we found buzz levels of up to 50 mA/m. While it is undoubtedly possible to reduce the magnetic buzz out of phones, Teder's experience and the lack of buzz-free digital cellphones on the market indicates that it may be cheaper to increase the signal level than to reduce the level of the buzz. This would have the additional advantage that higher-magnetic-signal cellphones would also allow greater freedom from interference from fluorescent lights and computer monitors.

If we take 50 mA/m as corresponding to conversational speech at 65 dB SPL (Teder, 2003, attached), then 500 mA/m would correspond to 85 dB SPL and 1700 mA/m would correspond to 90 dB SPL. In our limited experiments applying the "Link-it" technology to modify two digital cellphones to provide these levels of magnetic signals, the result is acceptable operation even when the cellphone has a relatively high magnetic buzz level output. Except for scratches, no change in the external appearance of the cellphones was required.

Although analog cellphones were once a temporary solution to both the RF and magnetic buzz problem, last week in a quick check we could not find a carrier willing to reactivate my perfectly-functioning old analog StarTac phone so we could use it as a buzz-free reference. (Thus the "analog solution" to telecoil usage appears less viable than it once was. This was not a real survey; we did not try all possible carriers).

PROPOSAL FOR CONSIDERATION

The preceding data and analysis leads to the following suggestion:

1. Since nearly all hearing aids will work with 80 mA/m signal strength in the absence of interference, a minimum magnetic field strength of 80 mA/m seems a reasonable requirement.
2. If the magnetic buzz level of a cellphone (measured in the plane of the earphone at the same locations specified in C63.19 for RF measurements) exceeds 4.5 mA/m, then the magnetic signal output of the cellphone must be 25 dB greater than the worst-case magnetic buzz level.

The combination of these two requirements would allow each cellphone manufacturer to choose the most economical method of providing adequate compatibility with hearing aids operating on telecoil in his product, each manufacturer to offer at least one compatible model as a start.

It was the caller's opinion that the implementation of greater directivity in RF cellphone antennas would increase the number of existing hearing aids that could be used with digital cellphones which were made telephone compatible.

NOTES REGARDING THE SUGGESTED MINIMUM OF 80 mA/m:

- a) If a designer were to design a good telecoil system from scratch, a higher level than 80 mA/m would be required. To quote Teder (2003), "Although the magnetic field of the U1 receiver and the resulting EIA standard were deemed hearing aid compatible and were the best available at the time, they were really just barely adequate and no more."

b) The field requirement for wireline telephones is 78 mA/m (EIA 504). Average speech level of wireline phones is about 85 dB, of a cellphone about 97 dB. As a matter of symmetry, the magnetic field of the cellphone thus should also be 12 dB higher than wireline, or about 320 mA/m at full volume control.

c) Even higher limits would be required if the magnetic signal level requirement out of the cellphone was set equivalent to the 97 dB SPL acoustic speech level required of cellphones at full volume setting. In this case, the requirement would be 2000 mA/m (based on 50 mA/m being equivalent to 65 dB SPL), and the user could turn down the volume if it was too strong a signal. In our experience such levels are practical if not necessarily required for good operation.

d) By way of review, sending 80mA rms of signal current through a single-turn coil 1 meter diameter provides 80 mA/m at its center.

e) Notwithstanding Teder's comment, levels of 30 to 80 mA/m have been accepted for years, and fluorescent lights and computer monitors were not caused by the introduction of digital cellphones. Thus it can be argued that if a digital cellphone can be designed with a magnetic buzz level below 4.5 mA/m, it should not have to produce more than 80 mA/m signal strength.

COST

In the short range, based on our low-volume production of devices producing high magnetic signal levels, we would expect the cost of retrofitting existing digital cellphones on a moderate-volume, as-needed basis would be less than \$5.00 in parts and perhaps less than twice that amount in labor. Thus it might be practical on an interim basis to make the top-of-the-line digital cellphone model, for example, available to those who wear telecoil hearing aids and request a telecoil compatible digital cellphone. There is a precedent for retrofitting: In 1974, bell system added extra coil in all coin phones, to produce adequate field.

In the long run (five years, for example), it might not be impractical to require all cellphones to be telecoil compatible (as FCC has required of wireline phones). We have received a quote from one of our suppliers that with enough time and adequate investment in completely automated manufacturing, the cost of the major component would be \$0.38 in tens-of-millions quantities. This same supplier suggested that at those quantities, however, the competitive nature of the cellphone industry would probably force prices below those levels, which is the callers guess as well.

Mead C. Killion, Ph.D., Sc.D. (hon)

President, Etymotic Research, Inc.

Adjunct Professor of Audiology at Northwestern University, Rush University, and at City University of New York Graduate School

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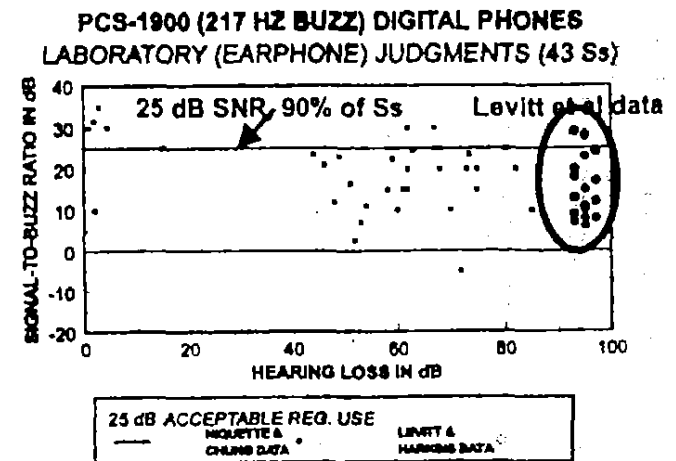
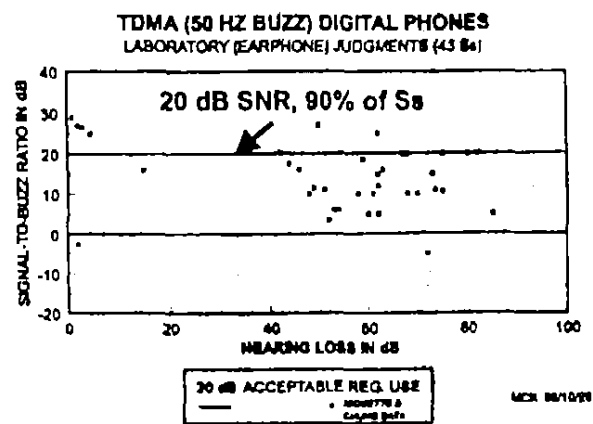


Figure 1 Signal-to-buzz ratios produced by TDMA and PCS-1900 DCTs for 43 wearers and their acceptable SNR. Reprinted from Killion (2000)²⁴ by permission.